The Aquatic Plant Community in Fawn Lake, Adams County 2002

MWBC:1301300
Deborah Konkel

Executive Summary

The aquatic plant community in Fawn Lake is below average quality and characterized by good diversity and a high tolerance to disturbance and poor water clarity. Aquatic plants occurred throughout Fawn Lake to the maximum depth of the lake. The greatest amount of plant growth was found in the 0-2ft depth zone. Filamentous algae was very abundant.

The abundant growth of the aquatic plant community is likely due to the fertile silt sediments, high alkalinity (hard water), gradually sloped littoral zone and eutrophic status. As a shallow water resource, abundant plant growth and clear water is the natural condition for Fawn Lake.

Ceratophyllum demersum, coontail, was the dominant species within the Fawn Lake aquatic plant community, especially in the 5-11ft depth zones. *Potamogeton crispus,* curly-leaf pondweed, was the sub-dominant species, dominating the 0-5ft depth zone. The two exotic species, *Myriophyllum spicatum,* Eurasian watermilfoil, and *Potamogeton crispus,* curly-leaf pondweed, made up 38% of the aquatic plant community in Fawn Lake.

Broad-spectrum chemical treatments may have facilitated the invasion of the two exotic species by opening areas for their colonization. Surveys conducted after these treatments had found little plant growth left in the lake.

Recommendations:

In order to protect Fawn Lake, it is recommended that the Lake District:

1) Encourage residents to restore a buffer zone of natural shoreline along the shore.
2) Develop an aquatic plant harvesting program to remove excess plant material and provide open channels for navigation and fish movement.
3) Conduct early-season harvesting to reduce *Potamogeton cripsus* in Fawn Lake.
4) Develop an aquatic plant management plan to facilitate obtaining permits for aquatic plant harvesting and grants for the cost-sharing of harvesting equipment.
5) Limit chemical treatments to those designed to be selective for the two exotic plant species.
6) Investigate nutrient sources to Fawn Lake. Grants for studies may be available from the state.
7) Start a water clarity monitoring program.

8) Winter drawdowns are not encouraged due to the lack of a reliable inflow into Fawn Lake for timely refilling.

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Fawn Lake was conducted during June 2002 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR). This was the first quantitative vegetation study of Fawn Lake by the DNR. The DNR had assessed the condition of the exotic aquatic plant species, *Potamogeton crispus* (curly-leaf pondweed) and *Myriophyllum spicatum* (Eurasian watermilfoil), in May 1999 and mapped their coverage in June 2001.

The present study was conducted during June to measure the impact of the exotic plant species on the aquatic plant community in Fawn Lake. The current study was also conducted to aid the lake in formulating an aquatic plant management strategy for Fawn Lake. A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants improve water quality, protect shorelines and the lake bottom, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

Background and History: Fawn Lake is a 19-acre impoundment on Trout Creek in southwest Adams County, Wisconsin. The dam for Fawn Lake was authorized in 1970-71.

Complaints concerning heavy aquatic plant growth were recorded as early as 1974. Investigations at that time found heavy growth of sago pondweed and leafy pondweed. Some coontail was also found.

The first recorded chemical treatments were in 1981. Between 1981 and 2002, several different chemicals were used to treat aquatic plants and algae (Table 1). Up to 10 acres had been treated in some years (more than half the lake) and multiple treatments had been conducted many of the years.

Table 1. Chemical treatments for Aquatic Plants in Fawn Lake

Year (# of treatments)	Diquat (gal)	Aquathol (gal)	AV-70 (gal)	CuSO4 (lbs)	2,4-D (gal)	Acreage Treated

1981(3)	3.75	14.5	6.5			4
1982(3)	4		6.5	11	5	7
1989(2)	3	2.5		15		8
1990	5			50		10
1991(2)	2	5		75		5
1992(2)	3.5	2		20		4
1993	2	2.5				4
1994(3)				150		5
1995(3)	5			100		5
1996(3)	3			100		7
1999					270#	3
2001					297#	3
2002					750#	5
Totals	31.25 gal	26.5 gal	13 gal	521 lbs	1317# 5gal	

Diquat and Aquathol are broad-spectrum chemicals that kill all plant species. DNR Fish Management reported that chemical treatments were removing nearly all the plant material in the lake (1995, internal memo). Removing large portions of the aquatic plant community left little habitat for fish, augmented the algae problem and set up an ideal situation for the introduction and colonization of the two exotic plant species in Fawn Lake.

AV-70 and CuSO4 are copper products that were used to kill algae (Table 1). The drawbacks of copper treatments are:
1) the very short effective time
2) the toxicity of copper to aquatic insects, an important part of the food chain in a lake
3) the build up of copper in the sediments, resulting in sediments that are toxic to mollusks that are the natural consumers of algae in a lake.

Recently, 2,4-D chemicals have been used to selectively treat the Eurasian water milfoil.

In 1999, Fawn Lake was drawn down for dam repair. The lake was left down over the winter in an attempt to help control Eurasian watermilfoil. Unfortunately, the spring of 2000 was dry and the lake remained below normal level most of the summer.

In 2002, the residents on Fawn Lake formed a Lake District in order to enable them to more effectively carry out programs to improve Fawn Lake.

II.METHODS

Field Methods

The study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 13 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix V), using a random numbers table.

One sampling site was randomly located in each depth zone (0-2 ft., 2-5 ft., 5-9ft. and 10-11ft.) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. The species recorded include aquatic vascular plants and algae that have morphologies similar to vascular plants, such as *Chara* sp. and *Nitella* sp. Each species was given a density rating (0-5) based on the number of rake samples at each sampling site on which it was present.
A rating of 1 for each species present on one rake sample;
A rating of 2 for each species present on two rake samples;
A rating of 3 for each species present on three rake samples;
A rating of 4 for each species present on four rake samples;
A rating of 5 indicates that a species was abundant on all rake samples at that sampling site.)

The presence of filamentous algae was recorded. The sediment type at each sampling site was also recorded. Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur at the sampling sites. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred / total number of sampling sites) (Appendix I). Relative frequency was calculated based on the number of occurrences of a species relative to total occurrence of all species (Appendix I). The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites) (Appendix II). Relative density was calculated based on a species density relative to total plant densities. A "mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density was summed to obtain a dominance value (Appendix III). Species diversity was measured by calculating Simpson's Diversity Index (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Weber et. al. (1995) was applied to Fawn Lake (Table 4). Values between 0 and 10 are given for each of six categories that characterize a plant community.

Average Coefficient of Conservatism and Floristic Quality (FQI) was calculated to determine disturbance as outlined in Nichols (1998). A coefficient of conservatism (C) is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients of Conservatism for all species found in a lake. The Floristic quality (FQI) is calculated from the Coefficient of Conservatism and is a measure of a plant community’s closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

WATER CHEMISTRY

NASA researchers have used satellite imagery to monitor lake water clarity calibrated from field measurements already collected by resource agencies and citizen monitoring efforts. A 2000 regional census of the lake clarity conditions in Minnesota, Wisconsin and Michigan has been produced which includes information on thousands of lakes that were previously unmonitored, including Fawn Lake. The satellite imagery produced by NASA's Regional Earth Science Application Center (http://resac.gis.umn.edu/water/regional_water_clarity/regional_water_clarity.htm) indicates that Fawn Lake is at the lower boundary of a eutrophic lake. This trophic state is associated with abundant nutrients and would result in lower water clarity and abundant aquatic plant growth (Appendix IV).

LAKE MORPHOMETRY - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Fawn Lake is a narrow, shallow impoundment with gradually sloped littoral zone (Appendix V). The gradually slopes and shallow depths would favor plant growth.

SEDIMENT COMPOSITION - Many species of plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a location.

Silt, an intermediate density sediment, was the predominant sediment in Fawn Lake, especially at depths greater than 5ft (Table 2). The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt (Barko and Smart 1986).

Sand and silt mixtures were predominant in the 0-5ft depth zone; sand sediment was common at depths less than 5 ft (Table 2).

Table 2. Sediment Composition in Fawn Lake, 2002

Sediment Type	0-2' Depth	2-5' Depth	5-10' Depth	10-11' Depth	Percent of all Sample Sites

Soft Sediments	**Silt**	28%	27%	85%	100%	40%
Mixed Sediments	**Silt/Sand**	44%	47%	14%		36%
Hard Sediments	**Sand**	25%	27%			24%

All sediment types supported vegetation in Fawn Lake.

MACROPHYTE DATA

SPECIES PRESENT

Eighteen species of plants were found in Fawn Lake in 2002:

- 6 were emergent species
- 2 was a free-floating species
- 10 were submergent species (Table 3).
- No threatened or endangered species were found.
- Two non-native species were found.
  - *Potamogeton crispus* – curly-leaf pondweed
  - *Myriophyllum spicatum* – Eurasian watermilfoil

Table 3. Fawn Lake Aquatic Plant Species

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Carex* sp.	sedge	carsp
2) *Juncus effusus* L.	soft rush	junef
3) *Phalaris arundinacea* L.	reed canary grass	phaar
4) *Scirpus validus* Vahl.	softstem bulrush	sciva
5) *Typha angustifolia* L.	narrow-leaf cattail	typan
6) *Typha latifolia* L.	common cattail	typla
Floating-leaf Species		
7) *Lemna minor* L.	small duckweed	lemmi
8) *Polygonum amphibium* L.	water smartweed	polam
Submergent Species		
9) *Ceratophyllum demersum* L.	coontail	cerde
10) *Chara* sp.	muskgrass	chasp
11) *Elodea canadensis* Michx.	common waterweed	eloca
12) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
13) *Myriophyllum spicatum* L.	Eurasain water milfoil	myrsp
14) *Najas flexilis* (Willd.) Rostkov & Schmidt.	slender naiad	najfl
15) *Potamogeton crispus* L.	curly pondweed	potcr
16) *Potamogeton nodosus* Poiret.	long-leaf pondweed	potno
17) *Potamogeton pectinatus* L.	sago pondweed	potpe
18) *Potamogeton pusillus* L.	small pondweed	potpu

FREQUENCY OF OCCURRENCE

Potamogeton crispus, curly-leaf pondweed, was the most frequently occurring species in Fawn Lake, (82% of sample sites) (Figure 1). *Ceratophyllum demersum, Chara* sp., *Lemna minor, Elodea canadensis* and *Myriophyllum spicatum* were also commonly occurring species, (80%, 34%, 41% and 52%).

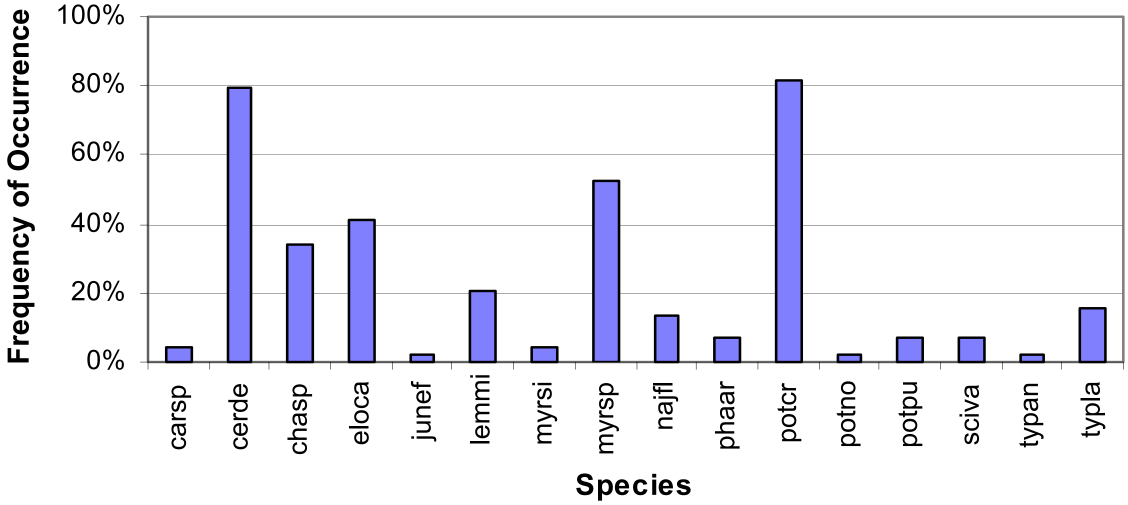

Figure 1. Aquatic plant frequencies in Fawn Lake, 2002.

Filamentous algae occurred at 77% of the sample sites.
At 88% of the sites in the 0-2ft. depth zone;
At 62% of the sites in the 2-5 ft. depth zone;
At 75% of the sites in the 5-10 ft. depth zone.
At 100% of the sites in the 10-11 ft. depth zone.

DENSITY

Ceratophyllum demersum, coontail, was the species with the highest mean density in Fawn Lake (2.11 on a density scale of 0-4) (Figure 2). *Potamogeton crispus,* curly-leaf pondweed, had the second highest mean density (1.95).

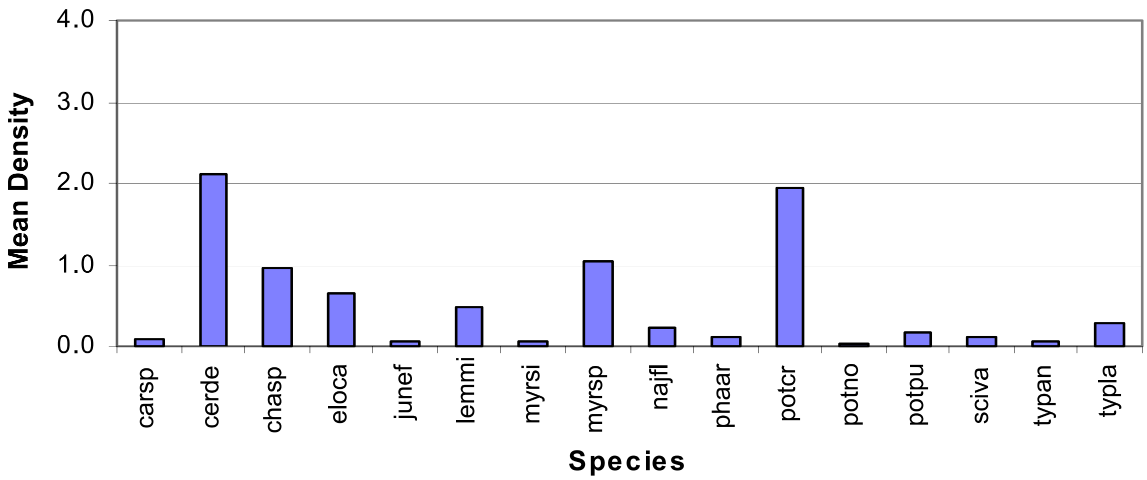

Figure 2. Densities of macrophytes in Fawn Lake, 2002

Elodea canadensis, common waterweed, had a 'mean density where present' of (2.8). The 'mean density where present' indicates that, *E. canadensis* exhibited a dense growth form in Fawn Lake; that where it occurred, it grew at an above average density (Appendix II). *Ceratophyllum demersum* (coontail) and *Potamogeton pusillus* (small pondweed) also had above average 'densities where present', indicating that they exhibited a dense growth form in Fawn Lake (Appendix II).

DOMINANCE

Combining relative frequency and relative density into a Dominance Value indicates how dominant a species is within the macrophyte community (Appendix III). Based on the Dominance Value, *Ceratophyllum demersum* (coontail) was the dominant species in Fawn Lake (Figure 3). *Potamogeton crispus* (curly-leaf pondweed) was sub-dominant, making up nearly one-quarter of the aquatic plant community. The other exotic species, *Myriophyllum spicatum* (Eurasian watermilfoil), comprises approximately one-eighth of the plant community (Figure 3).

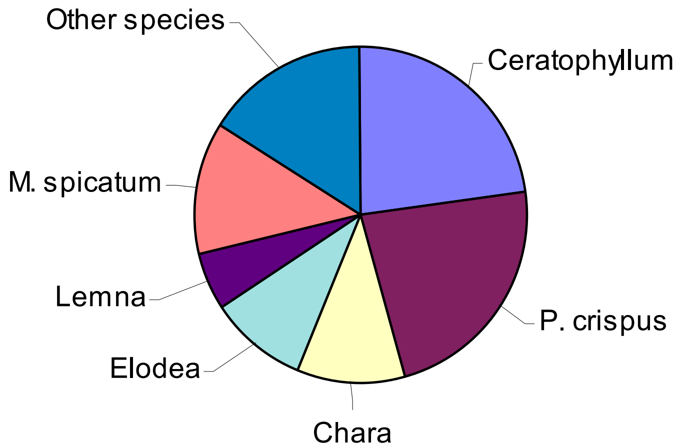

Figure 3. Dominance within the macrophyte community, of the prevalent macrophytes in Fawn Lake, 2002.

DISTRIBUTION

Aquatic macrophytes occurred throughout Fawn Lake, at all of the sample sites, to a maximum depth of 10.5 feet. *Ceratophyllum demersum* (coontail), *Myriophyllum spicatum* (Eurasian watermilfoil) and *Potamogeton crispus* (curly-leaf pondweed) occurred at the maximum rooting depth.

The greatest amount of plant growth occurred in the 0-2ft depth zone. The highest total occurrence and total density of plant growth was recorded in the 0-2ft zone (Figure 4). The greatest mean number of species per site was also found in the 0-2ft zone (Figure 5).

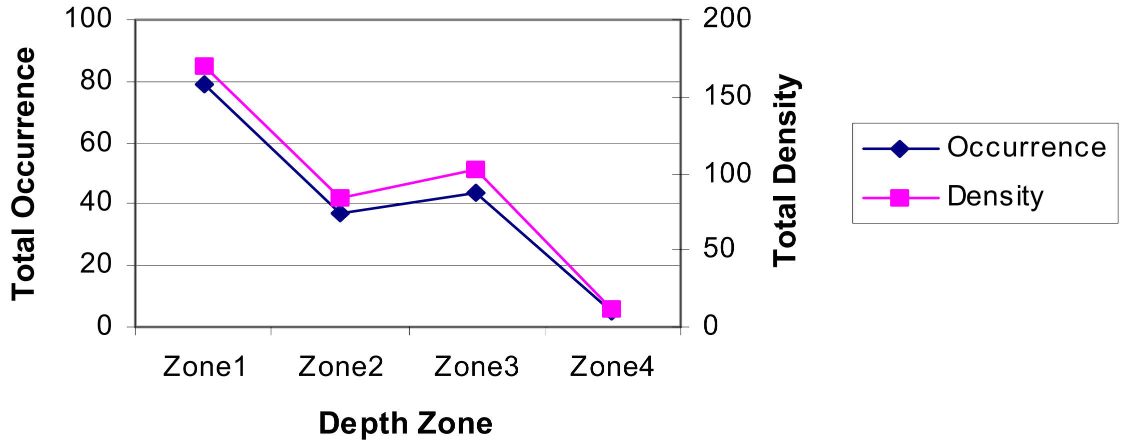

Figure 4. Total occurrence and density of plants by depth zone in Fawn Lake, 2002.

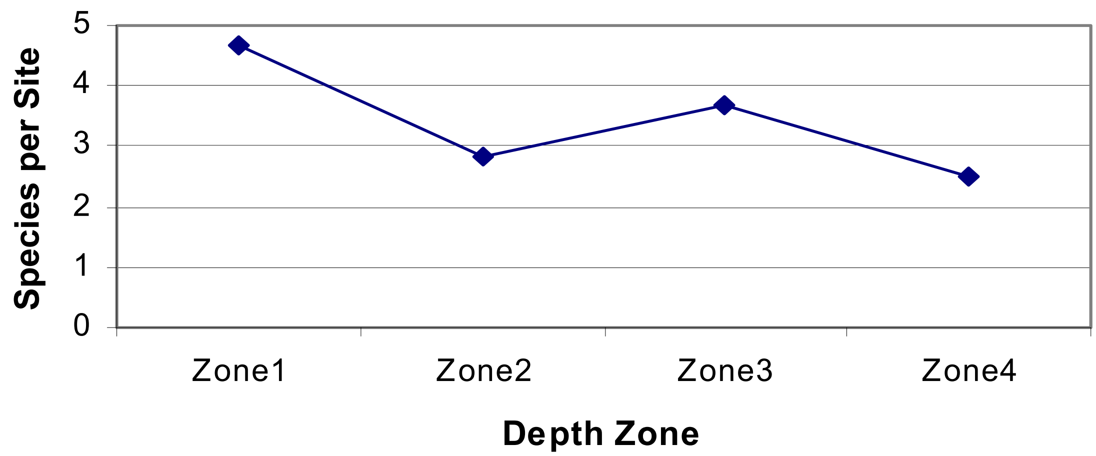

Figure 5. Mean number of species per sample site in Fawn Lake, by depth zone.

The mean number of species occurring at the sampling sites was 3.75.

The dominant species, *Ceratophyllum demersum* (coontail), was found throughout the lake and was the most frequent and the dense species in the 5-11ft depth zones. *C. demersum,* occurred at its highest frequency and density in the 5-11ft depth zone (Figure 6, 7).

Potamogeton crispus (curly-leaf pondweed), the sub-dominant species, occurred throughout the lake and was the most frequent and dense species in the 0-5ft depth zones. *P. crispus* occurred at its highest frequency and density in the 0-2ft depth zone

(Figure 6, 7).

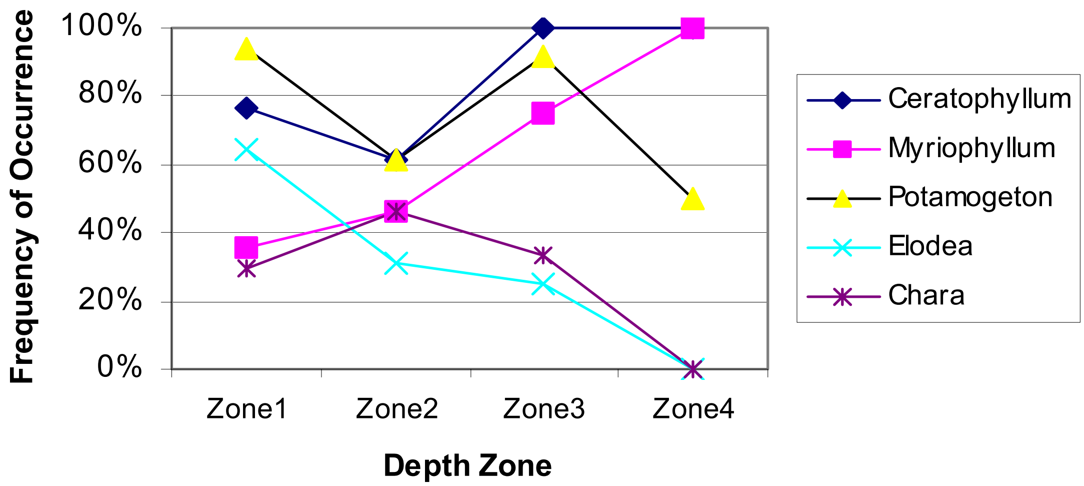

Figure 6. Frequency of occurrence of the prevalent macrophytes in Fawn Lake, by depth zone.

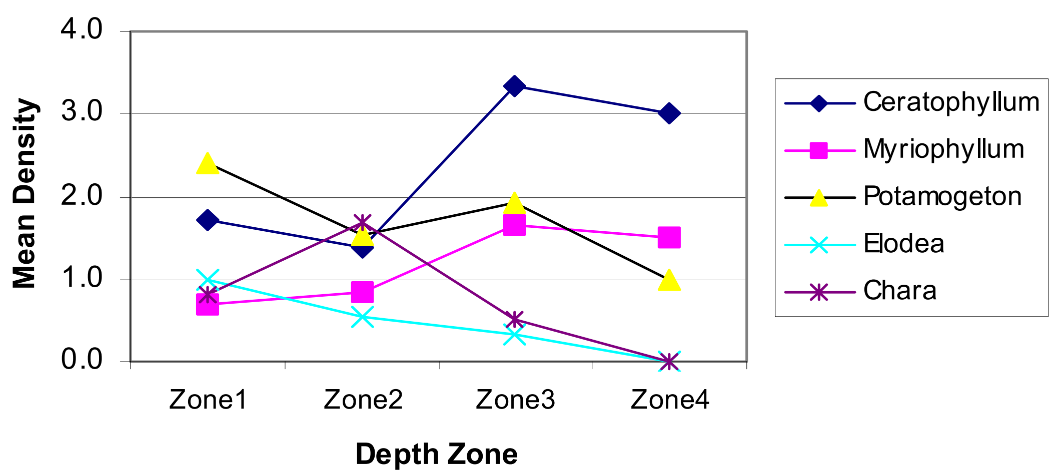

Figure 7. Density of the prevalent macrophytes by depth zone.

The other exotic species, *Myriophyllum spicatum* (Eurasian watermilfoil), occurred throughout the lake, except in the finger bay on the southwest corner. *M. spicatum* occurred at higher frequencies and densities in the 5-11ft depth zone (Figure 6, 7).

Elodea canadensis (common waterweed) was the species with the densest growth form in Fawn Lake, it occurred throughout the lake and at its highest frequency and density in the 0-2ft depth zone.

Chara sp. was found at a very high density in the 2-5ft depth zone, but only occurred in the west half of the lake.

THE COMMUNITY

Simpson's Diversity Index was 0.86, indicating a good diversity. An Index of 1.0 would mean that each plant sampled from the lake was a different species, the most diversity achievable.

Aquatic Macrophyte Community Index (AMCI) for Fawn Lake is 36. This is below average quality (40) for lakes in Wisconsin. The highest value for this index is 60. The low quality is due primarily to the abundance of the exotic plant species and the lack of sensitive species.

Table 4. Aquatic Macrophyte Community Index – Fawn Lake, 2002

Category	Fawn Lake	Value
Maximum Rooting Depth	3.2 meters	6
% Littoral Zone Vegetated	100%	10
Simpson's Diversity	0.86	9
# of Species	16 (2 exotics)	4
% Submergent Species	64% Rel. Freq.	7
% Sensitive Species	0% Freq.	0
Totals		36

The Average Coefficient of Conservatism for Fawn Lake was in the lowest quartile for all Wisconsin lakes analyzed and for lakes in the North Central Hardwood Region (Table 5). This suggests that the aquatic plant community in Fawn Lake is within the group of lakes in Wisconsin and the region that are most tolerant of disturbance.

Table 5. Floristic Quality and Coefficient of Conservatism of Fawn Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	(C)Average Coefficient of Conservatism †	Floristic Quality (FQI) ‡
Wisconsin Lakes *	5.5, 6.0, 6.9	16.9, 22.2, 27.5
NCHR *	5.2, 5.6, 5.8	17.0, 20.9, 24.4

Fawn Lake 2002	3.75	15.00

***** - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.
† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
‡ - The lowest Floristic Quality for Wisconsin Lakes was 3.0 (the most disturbance tolerant) and the high was 44.6 (the least disturbed).
North Central Hardwoods Region (NCHR), the region in which Fawn Lake is located.

The Floristic Quality of the plant community in Fawn Lake was also within the lowest quartile of Wisconsin lakes and North Central Hardwood Lakes (Table 5). This suggests that Fawn Lake is within the group of lakes in Wisconsin and the North Central Hardwood Region farthest from an undisturbed condition.

Disturbances can be of many types:

1) Direct disturbances to the plant beds can result from boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures, etc.
2) Indirect disturbances can be the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion, increased algae growth due to nutrient inputs.
3) Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores, destruction of plant beds by the fish population, etc.

The major disturbances in Fawn Lake have likely been the chemical treatments and the invasion of two exotic plant species.

2001 Assessment

The coverage of *Potamogeton crispus* (curly-leaf pondweed) and *Myriophyllum spicatum* (Eurasian watermilfoil) was mapped during a June 2001 assessment of Fawn Lake (Figure 8). Compared to the coverage of *Potamogeton crispus* and *Myriophyllum spicatum* in 2002, it appears that the coverage of *P. crispus* has remained relatively stable and the coverage of *Myriophyllum spicatum* has increased (Table 8).

<u>2001</u> **<u>2002</u>**

Figure 8. 2001 and 2002 coverage of *Potamogeton crispus* • and *Myriophyllum spicatum* •.

Two species that were recorded in 2001, did not occur in 2002: *Polygonum amphibium* and *Potamogeton pectinatus.*

V. DISCUSSION

Aquatic plant growth occurred throughout Fawn Lake, at all sampling sites, to a maximum depth of 10.5 ft. The 0-2ft depth zone had the greatest amount of plant growth. The highest total occurrence of plants, highest total density of plants and greatest mean number of species per sample site occurred in the 0-2ft depth zone. Filamentous algae was very abundant in Fawn Lake, occurring at 77% of the sample sites.

In 1974, state personnel conducted investigations due to complaints about heavy plant growth in Fawn Lake. They found heavy growth of sago pondweed and leafy pondweed. In 2002, sago pondweed was not found in Fawn Lake and leafy pondweed was found at a low frequency (7%). The 1974 assessment also found coontail as an infrequent species. In 2002, coontail was the dominant species.

Chemical treatments were conducted on Fawn Lake from 1981 to 2002. Broad-spectrum chemicals were used until 1996. Treatments covered more than half of the lake in some years and consisted of multiple treatments per year.

Post-treatment investigations found that much of the plant growth had been killed in the lake. The broad spectrum treatments likely reduced native pondweeds, opened up large areas and facilitated the invasion and spread of the two exotic species that Fawn Lake is dealing with at this time.

The predominance of silt sediments, the shallow depths, the eutrophic status and the gradual slope in the majority of the littoral zone favor aquatic plant growth in Fawn Lake.

Ceratophyllum demersum, coontail, was the dominant plant species in Fawn Lake in 2002, occurring throughout the lake and the dominant species in the 5-11ft depth zone. *Potamogeton crispus* was the sub-dominant plant species in Fawn Lake; dominating the 0-5ft depth zone and the most frequently occurring species overall. The two exotic species, *Myriophyllum spicatum,* Eurasian watermilfoil, and *Potamogeton crispus,* curly-leaf pondweed, make up three-eighths of the aquatic plant community in Fawn Lake. *Myriophyllum spicatum* was more abundant in the deeper depth zones and appears to have increased since 2001.

Three aquatic plant species, including the dominant species, exhibited a dense growth form in Fawn Lake.

More than half of the submerged aquatic plant species (including the dominant species) that occurred in Fawn Lake are species that are associated with poor water clarity, soft sediments and water of high pH and alkalinity (hard water) (Nichols 1999).

The Aquatic Macrophyte Community Index (AMCI) for Fawn Lake was 36, indicating that the quality of the macrophyte community in Fawn Lake is below average (40) for Wisconsin lakes. Simpson's

Diversity Index (0.86) indicates that the macrophyte community had good diversity. The mean number of plant species per sample site was 3.75.

The Floristic Quality Index indicates that Fawn Lake is within the group of lakes in Wisconsin and in the North Central Hardwoods Region of Wisconsin that are most tolerant of disturbance and farthest from an undisturbed condition. This suggests that Fawn Lake is among the group of lakes that has been subjected to the most disturbance. The disturbances that have impacted the plant community in Fawn Lake likely include broad-spectrum aquatic chemical treatments, input of nutrients as suggested by the high algae growth and the invasion of two exotic plant species.

VI. CONCLUSIONS

The aquatic plant community in Fawn Lake is below average quality and is characterized by good diversity and a high tolerance to disturbance and poor water clarity. Aquatic plants occurred throughout Fawn Lake to the maximum depth of the lake. The greatest amount of plant growth was found in the 0-2ft depth zone. Three species grew at above average densities. Filamentous algae was very abundant.

The abundant growth of the aquatic plant community is likely due to the fertile silt sediments, shallow depths, high alkalinity (hard water) and pH of the water and gradually sloped littoral zone. As a shallow water resource, abundant plant growth and clear water is the natural condition for Fawn Lake.

Ceratophyllum demersum, coontail, was the dominant species within the Fawn Lake aquatic plant community, especially in the 5-11ft depth zones and exhibiting a dense growth form. *Potamogeton crispus,* curly-leaf pondweed, was the sub-dominant species, dominating in the 0-5ft depth zone. The two exotic species, *Myriophyllum spicatum,* Eurasian watermilfoil, and *Potamogeton crispus,* curly-leaf pondweed, made up 38% of the aquatic plant community in Fawn Lake.

The 2002 aquatic plant community is changed from the 1974 aquatic plant community that was assessed before chemical treatments were started. *Ceratophyllum demersum* has increased from a low frequency species to the dominant species. The two native pondweeds that were dominant in 1974, now occur at very low frequencies in Fawn Lake. Broad spectrum chemical treatments may have facilitated these changes and opened up areas for the invasion of the two exotic species. Post-treatment surveys found little plant growth left in the lake.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in
1) improving water quality 2) providing valuable resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species and reduce diversity.

Macrophyte communities improve water quality in many ways:
1) trap nutrients, debris, and pollutants entering a water body;
2) absorb and break down some pollutants;
3) reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
4) remove nutrients that would otherwise be available for algae blooms (Engel 1985).

Aquatic plant communities provide important fishery and wildlife resources. Plants (including algae) start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table

6).

Compared to non-vegetated lake bottoms, macrophyte beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of macrophytes support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species.

Cover within the littoral zone should be 25-85% to support a healthy fishery. Macrophyte beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990). The aquatic plant beds in Fawn Lake provide cover 100% of the littoral zone. This amount of coverage provides more than adequate cover for fish and may be too dense for a balanced fish community.

Recommendations:
In order to protect Fawn Lake it is recommended that the Lake District:

1) Encourage lake residents to restore a buffer zone of natural shoreline along the shore. Natural shoreline reduces run-off of nutrients and sediments into the lake; it filters the run-off that does enter the lake; it helps prevent shoreline erosion. Lawn cover results in increased run-off of nutrients, pesticides and pet wastes into the lake.
2) Develop an aquatic plant management plan in order to facilitate obtaining permits for aquatic plant harvesting and grants for the cost-sharing of harvesting equipment.
3) Develop an aquatic plant harvesting program to remove excess plant material and provide open channels for navigation and fish movement. The harvesting plant should be designed to address:
    a) Conduct early-season harvesting to reduce *Potamogeton cripsus* in Fawn Lake. The harvesting should begin early enough to not only remove curly-leaf pondweed biomass, but to also prevent the formation of turions that will provide the next year’s curly-leaf pondweed growth. The areas to conduct early season harvesting are those areas that support curly-leaf pondweed.
    b) Mid-summer harvesting would be designed to cut navigation and fish-cruising lanes in areas of dense Eurasian watermilfoil beds.
4) Investigate nutrient sources to Fawn Lake. High nutrients are suggested by the abundance of filamentous algae and the tolerance of the aquatic plant community to poor clarity.
5) Monitor water clarity through the Self-Help Volunteer Lake Monitoring Program.
6) Any chemical treatments must be designed to be selective for the two exotic plant species. It should also be realized that chemical treatments allow the plant material to decay in the lake, which will promote algae growth.

7) Limit copper treatments. Copper treatments have very limited effectiveness. This very small benefit is set off by could have reduction of the food source for fish by killing the invertebrates on which they feed and its toxicity to clams and snails (mollusks) that are the natural algae feeders in a lake.
8) Winter drawdowns are not encouraged due to the lack of a reliable inflow into Fawn Lake for timely refilling.

Appendix V. Location of Survey Transects